

UNCLASSIFIED INFORMATION DATA

Gravitational and Resonance Experiments on
Very Low-Energy Free Electrons and Positrons

Progress Report for Period
1 February 1964 to 1 December 1964

GPO PRICE \$

OTS PRICE(S) \$

Hard copy (HC) 1.00

Microfiche (MF) .50

Work Performed at Stanford University
Under Research Grant NsG-378
National Aeronautics and Space Administration

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FACILITY FORM 602	N65 14935	
	(ACCESSION NUMBER)	(THRU)
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	CR 60104	23
	(INASA CR OR TMX OR AD NUMBER)	(CATEGORY)

Gravitational Experiment on Electrons

The principal investigator for this research is Professor William L. Fairbank. Two full-time graduate students, Larry V. Knight and Fred C. Witteborn worked on the experiment throughout the period of this report.

Experiments were performed on the pilot model throughout 1964. A paper on the results up to April 1964 was presented at the 101st Meeting of the National Academy of Sciences in Washington, D.C. in April 1964; an abstract of the paper was published in Science, Vol. 144, pg. 562. A copy is enclosed with this progress report. The results up to September were reported at the IX International Conference on Low Temperature Physics. The report, entitled "Use of Low Temperature Techniques," will be published in the Proceedings of the above mentioned conference. A preprint is attached. We have also enclosed portions of a letter to Mr. Robert Hall, II, of General Electric Company, which describes our observations on the behavior of tunnel cathodes at low temperatures. These cathodes operate quite well at 4.2°K and can be pulsed - a critical requirement of our time of flight method of determining electron energies. They have been our source of electrons throughout the pilot model experiments and will be used in the larger apparatus as well.

Early in 1964, the lower limit of electron energies was reduced to about 10^{-11} electron volts by increasing the length over which the drift tube was free of magnetic fields. This was done with a superconducting shield.

Further experiments were hampered by a poor vacuum and later by contamination of the drift tube. The $N(T) = N(0)T^{-2}$ distribution (where $N(T)$ is the number of electrons taking time T or longer to traverse the drift tube). became mixed with a $N(0)T^{-1}$ component. An experiment was devised which would enable us to mass analyze the particles in the drift tube.

By running an electric current axially through the walls of the drift tube, a weak uniform electric field was produced along the axis of the tube. Thus, a known force could be exerted on the slow particles moving through the drift tube. If this force is larger than others present in the drift tube, it limits the particle flight times to $t_{\max} = \sqrt{\frac{2mh}{eE}}$ where h is the length of the tube, m is the particle mass, e the charge on the particle, and E the electric field strength. The limit on the time of flight

distribution should be the same whether the electric field aids the particle or opposes it. In a series of runs performed on May 25th a distribution was first obtained with zero electric field. Its maximum flight time was beyond 160 msec. Then a downward electric field of about 10^{-6} volts/meter was applied. The flight times were cutoff at about 80 msec. When the field was reversed the cutoff appeared between 70 and 80 msec. The particle mass calculated from these numbers is several thousand times too large for electrons, but just right for light negative ions.

In several experiments in which the $N(o)T^{-1}$ distribution was observed (with no applied electric field), there was a distinct cutoff at $T = 176\text{msec}$. This is exactly equal to the maximum flight time predicted for a particle under the influence of gravity in the pilot model drift tube. To our knowledge this is the first observation of the gravitational effect on freely falling ions.

The increasing abundance of ions in the drift tube was coincident with the deterioration of the vacuum pump. Replacement of the vacuum pump eliminated the ions from the drift tube. Slow electrons were not observed, however, until after the drift tube surface had been replaced by a new graphite coated insert tube. Graphite is known to have relatively low contact potential variations. While we found no particular advantage over fresh electropolished copper, the new tube did enable us to see slow electrons again.

Before buying the equipment for the large free-fall apparatus, we felt it wise to demonstrate more conclusively that the long electron flight times resulted from their low velocities rather than temporary trapping somewhere in the drift tube. To do this, we modified the sequence of operations as described below. A pulse of electrons was emitted from the cathode at time $t = 0$ as usual. From time t , to time $t + S$, a negative voltage appeared at the detector, causing electrons reaching the detector to go back down the tube. At the same time the cathode was made negative for the remainder of the run, so that electrons coming down the tube had to go back up again. Thus, electrons that should have arrived between t , and $t + S$, had to traverse the drift tube three times before finally entering the detector between $3t$, and $3(t + S)$. Since the number of electrons ordinarily drops off rapidly with flight time, the additional electrons arriving at time $3t$,

would produce a pronounced peak in the distribution. If the electrons were not really slow moving, those repelled at t , would reach the detector long before $3t$, and no peak would appear in the distribution. A peak was actually observed at $3t$, for energies as low as 8×10^{-10} electron volts. This was the lowest energy tried. We have no reason to think that lower energy electrons were not present, but only one energy can be checked at a time and the time required to do such an experiment increases greatly as the energy is lowered. Furthermore, this energy was low enough to insure that a larger free-fall apparatus could measure the effect of gravity on electrons and positrons.

The large free-fall apparatus is under construction. The large drift tube (108 inches long, 2 inches diameter) is designed and the materials ordered. The dewar has been ordered. We are waiting for a bid on the large guide magnet. We expect the apparatus to be operating by June, 1965.

G-2 Experiment

There are three main factors which affect the accuracy with which $g-2$ can be measured: (1) the time of flight of the free electrons; (2) the stability of the oscillating field; (3) the homogeneity of the magnet.

The pilot model results have proven that time of flight is no limitation and a continuous microwave source which is stable to better than one part in 10^{11} has been assembled and tested. Calculations have been made that indicate that it is feasible to build a magnet with sufficient homogeneity to make a measurement of " $g-2$ " to one part in 10^8 possible. Linde Company after making independent calculations have agreed to furnish such a magnet. Delivery is expected in early December.

The drift tube, resonant cavity, dewar, and vacuum system have been constructed and partially tested. An actual measurement is possible in the next months.

References

- ¹P. Morrison and T. Gold, Essays on Gravity (New Boston, N.H.: Gravity Res. Foundation, 1957), p. 45
- ²J. H. Parker, Jr. and R. W. Warren, Review of Sci. Inst. 33 No.9, September 1962, p. 948.